Lasers in Manufacturing Conference 2023

Green laser welding process and system technologies for manufacturing parts of electric vehicles

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Abstract

Electric vehicles generally use lithium ion batteries with high energy density, and types include prismatic, pouch-type, and cylindrical batteries. In the electric vehicle industry, stable quality is important for electric vehicle battery welding. In addition, in the case of dissimilar materials, in copper-steel welding, the two materials do not form an intermetallic compound due to low solubility with each other, and segregation inside the welded part causes brittleness, which can lead to deterioration of welding quality. Therefore, it is important to set the laser parameters. Therefore, in this study, nickel-coated copper-mild steel materials used in battery tabs and bus bars were welded using a green laser through various process conditions and scan patterns in order to have more stable welding quality. Optimal process parameters that minimize spatter, internal defects, and internal segregation of welds were suggested through excellent mechanical properties and surface and cross-section analysis.

Keywords: greem; laser; welding; electrical vehicle; battery

1. Introduction

Electric vehicles generally use lithium ion batteries with high energy density, and types include prismatic, pouch-type, and cylindrical batteries. These batteries are composed of hundreds or thousands of battery cells, and tabs and busbars are used to electrically connect them. In general, battery taps and busbars are made of

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copper, which is a good electrically conductive material, but in recent years, aluminum has been used to reduce the weight of battery busbars and steel has been used to increase the mechanical strength and corrosion resistance of can battery cases. In the electric vehicle industry, stable quality is important for electric vehicle battery welding. In addition, in the case of dissimilar materials, in copper-steel welding, the two materials do not form an intermetallic compound due to low solubility with each other, and segregation inside the welded part causes brittleness, which can lead to deterioration of welding quality. Therefore, it is important to set the laser parameters.

In this study, nickel-coated copper-mild steel materials used for battery tabs and case were welded using a green laser through various process conditions and scan patterns in order to have more stable welding quality. Optimal process parameters that minimize spatter, internal defects, and internal segregation of welds were suggested through excellent mechanical properties and surface and cross-section analysis.

2. Experimental Equipment

Figure 1 shows the developed system of the remote green laser welding system. The beam from the laser generator is transmitted via an optical fiber to the welding head at the end of the robot's arm. The laser welding can be achieved by manipulating the industrial robot system. The laser generator used was 2 kW green laser system and the robot system was the 6 axes Industrial robot of payload 60 kg. To conduct a basic study of the weldability of the remote laser welding system, the lap welding was conducted with the common nickel coated copper and mild steel sheets. The weld joints were inspected and tested for shear tensile strength to determine the optimal welding parameters. In order to study the technology of measuring the laser welding quality in real time, a device capable of monitoring plasma, temperature, and reflected beam was constructed, and a basic laser welding process monitoring experiment was conducted. The pattern welding tests were conducted to examine the accuracy of the entire remote laser welding system.

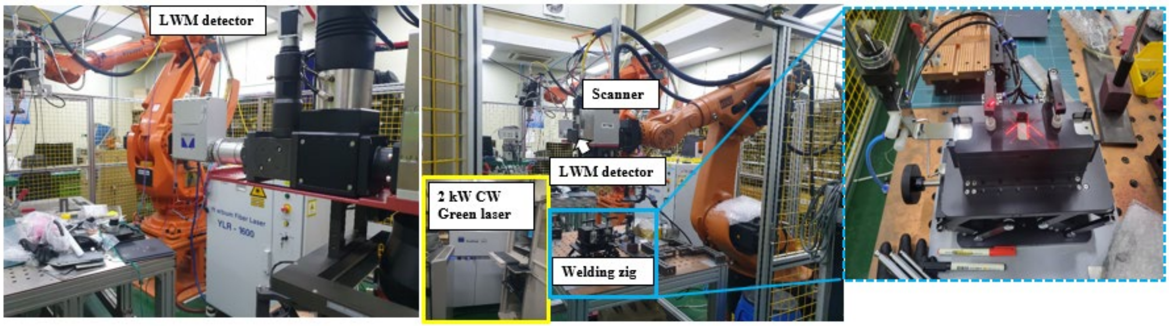


Fig. 1. remote green laser welding system

Figure 2 shows the process sequence of laser welding monitoring system. During the laser welding on a real-time-basis, the basic tests were conducted to develop a technique which facilitates the evaluation of weld quality by monitoring plasma, temperature, and back reflection beam. The tests were conducted using the green laser. To monitor laser weld quality using plasma intensity, the initial criteria of plasma intensity, which determines the critical weld quality, needs to be determined. When the plasma intensity lies between the maximum and minimum values of the standard range as Figure 3, the weld quality can be judged to be acceptable.

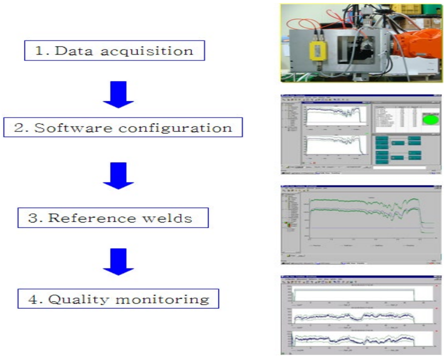


Fig. 2. Process sequence of laser welding monitoring

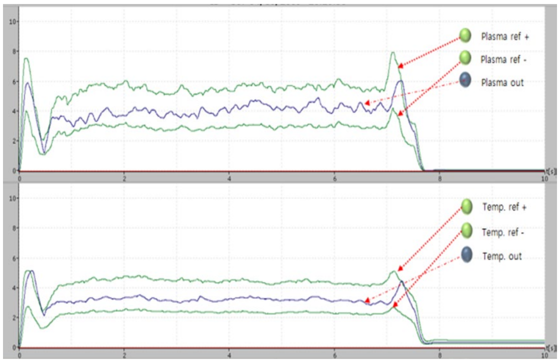


Fig. 3. The result of green laser welding monitoring by using reference curve

3. Test results

Figure 4 shows the schematic diagram of laser welding specimens. In the green laser welding tests, dissimilar light metals of the nickel coated copper and mild steel sheets were welded at laser powers of 1.2 kW (60%), 1.6 kW (80%), and 2 kW (100%) and welding speeds of 250, 300, and 350 mm/s. Table 1 shows laser welding conditions of samples. The diameter of laser beam is about 182 um and the focal length of laser objective lens is 340 mm. The results were obtained by scanning the specimens by using the laser scanner of the laser welding system. Figure 5 shows the optical microscope images of top section (a) and cross section (b). Figure 6 shows the results of shear tensile test (a) and laser welding monitoring (b).

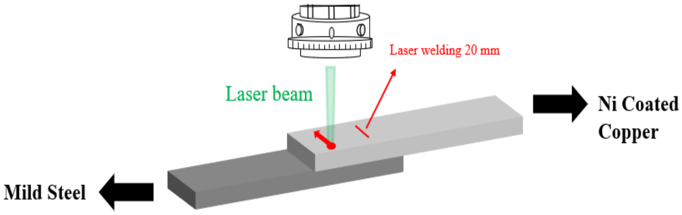
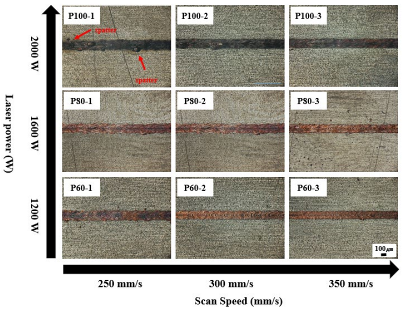


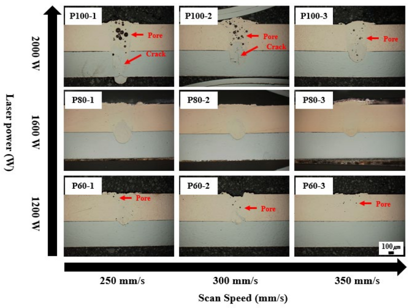
Fig. 4. the schematic diagram of laser welding specimens

Table 1. laser welding conditions of samples

Laser power	1.2 kW (60%)	1.6 kW (80%)	2 kW (100%)
Welding speed: 250 mm/s	P60-1	P80-1	P100-1
Welding speed: 300 mm/s	P60-2	P80-2	P100-2
Welding speed: 350 mm/s	P60-3	P80-3	P100-3

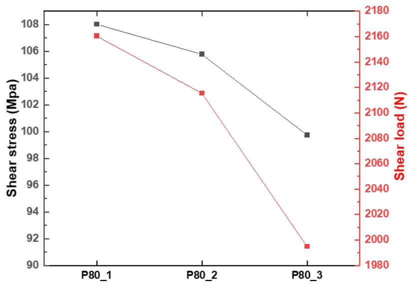


(a)

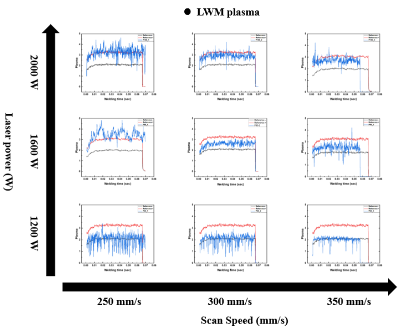


(b)

Fig. 5. the optical microscope images (a) top section of welding beads; (b) cross section of welding beads



(a)



(b)

Fig. 6. Test results (a) shear tensile test; (b) laser welding monitoring of plasma

4. Conclusions

In this study, the welding characteristics of copper-steel dissimilar materials were studied using a green laser. A welding experiment was conducted by varying the laser power and scan speed, and a laser welding monitoring experiment was conducted to measure the process quality in real time. After the laser welding experiment, the surface and internal defects were confirmed, and the mechanical properties were confirmed through the test. The results are summarized as follows.

After laser welding, the P80 condition showed no surface or internal defects, and the P100 condition showed internal porosity and cracks. A small amount of porosity exists even under the P60 condition. Among the P80 conditions, the P80-1 condition has a fire risk due to the deep penetration depth, and the P80-3 condition has a joint problem, so the P80-2 condition was set as the optimal condition.

The mechanical property result confirmed that the shear stress value increased as the heat input increased for P100, P80, and P60. As a result of the microhardness measurement test, as the heat input increased, the microhardness value increased as more iron-copper elements were mixed and more martensitic microstructures were formed.

For the laser welding monitoring test result, the experiment was conducted by setting the optimal condition P80-2 as a reference. The results of the monitoring experiment showed that the plasma and temperature signal increased as the heat input increased, and the plasma and temperature signal decreased as the heat input decreased. The reflected light signal tended to increase as the scan speed increased.

In conclusion, in this study, green laser was applied to laser welding of copper-steel battery materials to derive optimal conditions for stable welding quality, and welding quality could be measured in real time through laser welding process monitoring.

Acknowledgements

This research was funded by the Korea Evaluation Institute of Industrial Technology, Korea (project no. 20015063, 20014348).

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